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Features of various parts of the arcuate fasciculus mapping in patients with left hemisphere gliomas: analysis of 23 awake brain surgeries

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Background. Awake craniotomy is a modern technique of neurosurgical operations allowing to preserve speech while trying to achieve maximal tumor resection. For a long time, during awake surgeries the main importance was assigned to electrostimulation of the language centers. Currently, the mapping of the long association tracts during resection of gliomas of the speech-dominant hemisphere is the necessary requirement for speech preservation.

Aim. To analyze the results of intraoperative electrostimulation of the arcuate fasciculus in comparison with magnetic resonance tractography data (MR tractography), as well as speech disorders before and after surgical interventions in patients with left hemisphere gliomas adjacent to the arcuate fasciculus who underwent awake craniotomy.

Materials and methods. Awake surgeries were performed in 23 patients aged between 19 and 67 years old (mean age 41) with left hemisphere glionas. Tumor was located in the frontal lobe in 11 patients, in the temporal lobe – in 8 patients, in the parietal lobe – in 4 patients. The malignancy grade was the following: Grade 2–7 patients, Grade 3–12 and Grade 4–4 patients. In all patients, the cortical electrophysiological stimulation to control localization of the cortical language centers and subcortical electrophysiological stimulation for identification of the arcuate fasciculus were performed during awakening. Speech disorders before and after surgery were evaluated by a neuropsychologist using the Luria method; intraoperatively, automated test with picture naming was additionally used. The mean current intensity during direct subcortical electrostimulation was 4 mA. MR tractography with reconstruction of the arcuate fasciculus and volumetry using magnetic resonance imaging (MRI) were performed in all 23 cases before and after surgery.

Results. During intraoperative electrostimulation, Broca's area was identified in 8 of 11 patients with frontal lobe tumors, cortical temporal speech areas were identified in 5 of 8 patients with temporal lobe tumors. In 16 (70 %) of 23 patients, the arcuate fasciculus was mapped in the form of mixed speech abnormalities in the depth of operative wound in the frontal, parietal and temporal lobes. In 17 (75 %) of 23 patients, worsening the speech function was observed in the early postoperative period: in 13 of them a combination of frontal and temporal types of speech disorders (conduction aphasia caused by the surgery near the arcuate fascisulus) was observed. The postoperative MR tractography performed in 23 patients showed the direct intraoperative injury of the arcuate fasciculus in 3 (13 %) cases and adjacent ischemia – in 2 (9 %) cases. The MR volumetry showed total tumor resection in 8 cases, subtotal – in 9 cases, and partial – in 6 cases.

Conclusion. During awake surgeries for left hemisphere tumors, it is important to map the arcuate fasciculus in the deep parts of the frontal, temporal and parietal lobes. The subcortical stimulation allowed to identify the arcuate fasciculus in 70 % of presented cases; the MR tractography showed the damage of the anatomical integrity of the arcuate fasciculus in 22 % of cases (direct injury or ischemia). Worsened speech function after surgery was observed in 75 % of patients. In the early postoperative period, the main cause of worsened speech function related to the arcuate fasciculus is its functional insufficiency but not an anatomical damage. These speech disorders regress in the majority of patients (85 %) in 3–6 months after surgery.

Keywords: arcuate fasciculus mapping, glioma, awake surgery, aphasia, speech disorder

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BACKGROUND

Gliomas are the most common primary tumors of the central nervous system, accounting for more than 80 % of its total number. The results of the most studies show that increasing the volume of glioma resection leads to a decrease in the number of relapses and an increase in life expectancy [1]. When the tumor is located near the speech areas, the maximum resection can cause persistent neurological deficit, which significantly reduces the patient's quality of life. Therefore, it is important to preserve the function of the speech centers during such operations [2].

The current methods of functional neuroimaging, such as functional magnetic resonance imaging (fMRI) and magnetic resonance tractography (MR tractography), have increased the efficiency of neurosurgical operations planning, including tumors located near speech areas. However, these methods are not absolutely accurate. The preoperative MR tractography data download into a neuronavigation system is also an unreliable method, since "brain shift" occurs during surgery. Therefore, awake surgery remains the "gold standard" for speech areas mapping [3].

As it is known, gliomas spread along the fibers of the white matter, and therefore during operations with awakening in order to preserve speech functions, it is necessary to map not only the cortical speech centers, but also the speech tracts. It should be noted that long association tracts are more sensitive to damage than cortical speech centers.

The intraoperative white matter mapping is performed using direct electrical stimulation. However, the subcortical direct electrical stimulation of the arcuate fasciculus, in contrast to the pyramidal tract, has not been sufficiently studied to nowadays [4].

This article is a continuation of the previous studies by a group of authors from the Burdenko National Medical Research Center of Neurosurgery [5–7] and presents an analysis of observation series, including 23 patients with high- and low-grade gliomas located in the left hemisphere near the arcuate fasciculus, in whom the both cortical and subcortical mapping were performed, as well as an analysis of intraoperative and postoperative speech disorders.

The **aim** of the study is to analyze the results of intraoperative electrical stimulation of long association tracts in comparison with pre- and postoperative MR tractography data, as well as to assess speech disorders in patients with left hemisphere gliomas adjacent to the arcuate fasciculus, who were operated on using the awake craniotomy technique.

MATERIALS AND METHODS

The criteria for patients inclusion in the study group were the following: availability of MR tractography with reconstruction of the arcuate fasciculus before and after surgery; the tumor location near the arcuate fasciculus at a distance of not more than 2.0 cm or infiltration of this fasciculus according to preoperative MR tractography.

The exclusion criteria were the following: significant speech impairments before surgery (errors in naming more than 25 % of pictures according to an automated test) and repeated surgical interventions.

The awake craniotomies were performed in 23 patients aged 19 to 67 years old (mean age 41) with left hemisphere gliomas. The patients' data of the study group are presented in Table 1.

Table 1. The characteristics of patients in the study group (*n* = 23)

Characteristic	Number of patients, *n*
Sex:	
men	8
women	19
Tumor localization:	
frontal lobe	11
temporal lobe	8
parietal lobe	4
Histological characteristics:	
low-grade gliomas:	8
dysembrioplastic neuroepithelial tumor	1
diffuse astrocytoma	3
oligodendroglioma	4
high-grade gliomas:	15
anaplastic astrocytoma	5
anaplastic oligodendroglioma	6
glioblastoma	4

All patients underwent a comprehensive neuropsychological examination using the method of A.R. Luria [8] before surgery and on the 4th–6th postoperative day. This method allows to perform the detailed qualitative analysis of the detecting disorders, their mechanisms, and also to establish the topical affiliation of the symptoms observed.

The various types of praxis, qualitative features of speech functions (including writing and counting), spatial functions, auditory and visual gnosis as well as thinking were studied. The particular reference was made to the assessment of speech function, with spontaneous speech, naming, understanding, repetition, and writing under dictation.

To assess the vocabulary and speech function inertia, a speech fluency test was performed with naming words with a given feature (red or green objects, nouns starting with the letter "K" or "C" in cyrillic alphabet) for 1 minute. In addition, all patients completed a computerized naming test before and after surgery.

For intraoperative speech monitoring, a computerized test [9] was also used with naming nouns or verbs based on simple black-and-white pictures (a total of 50 pictures depicting actions or objects), and automated series were also assessed (counting from 1 to 10, listing months, days of the week). During the entire period of awakening, against the background of continuous subcortical electrical stimulation during tumor removal, a free dialogue was carried out with the patient (he was asked questions about the main stages of his life).

All patients underwent magnetic resonance imaging (MRI) with contrast enhancement and MR tractography with arcuate fasciculus reconstruction before and after surgery. The relationship between the arcuate fasciculus and glioma was assessed – intactness, dislocation, or fiber infiltration. After surgery, fasciculus damage was additionally assessed (its rupture and ischemia of fasciculus area according to MRI data in the diffusion-weighted imaging mode). All patients underwent fMRI with determination of Broca's and Wernicke's areas before surgery.

The surgical intervention was performed with intraoperative awakening of patients according to the asleep-awake-asleep protocol. All 23 patients underwent cortical and subcortical electrophysiological stimulation to control the localization of functionally significant structures and to clarify the accetable volume of tumor resection. After opening the dura mater, an 8-contact electrode was placed on the cortex to record an electrocorticogram to control the appearance or increase of epileptiform activity due to electrical stimulation.

The cortex electrical stimulation was performed with single rectangular pulses of 1 ms duration with a stimulus frequency of 50 Hz (according to Penfield). The stimulus amplitude in most cases was 4 mA. If the patient had typical epileptiform components according to the initial (before stimulation) electrocortigraphy data, the stimulus intensity was reduced to 2 mA.

If a negative effect was obtained with a standard stimulation level in the cortex where the speech area was presumably localized according to fMRI data, a repeated test was performed. In this case, the stimulus intensity was increased to 5–6 mA. A standard bipolar two-contact electrode was used as a stimulating probe.

During tumor removal, the continuous subcortical electrical stimulation was performed using a special ring electrode connected to a vacuum aspirator. Monopolar cathodic stimulation was performed with the same technical parameters as during cortex stimulation. The reference electrode (anode) was located at the Fz point. The stimulus intensity during subcortical stimulation was 4 mA.

After the speech disorders appearance during dynamic monopolar stimulation, bipolar stimulation was additionally used to clarify the localization of the white matter tracts (bipolar probe, current from 4 to 8 mA). In 18 patients, monopolar and bipolar stimulation was used subcortically, and in 5 patients – only bipolar stimulation.

RESULTS

Preoperative examinations

Preoperatively the speech was normal in 16 of 23 patients. The nature of complaints and cognitive status before surgery directly depended on the degree of tumor malignancy. Patients with glioblastomas were found to have predominantly mild acoustic-amnestic aphasia (according to A.R. Luria) with impaired naming and auditory-verbal memory; in case of anaplastic gliomas a combination of epileptic seizures and mild speech disorders (such as efferent motor (Broca's aphasia) and acoustic-amnestic aphasia) was observed, and in patients with low-grade gliomas, epileptic syndrome was noted before surgery. In addition, the neuropsychological examination revealed auditory-verbal memory disorders of varying degrees in most patients. All patients in the study group were right-handed.

According to preoperative fMRI data, Broca's area was detected in all 11 patients with frontal lobe tumors; Wernicke's area was also revealed in all 8 patients with temporal lobe tumors.

The ratio of the arcuate fasciculus to tumor according to MR tractography data is shown in Table 2.

Table 2. The data of magnetic resonance tractography with reconstruction of left arcuate fasciculus before and after surgery ($n = 23$)

Fasciculus state	Before surgery, *n*	After surgery, *n*
Intact	6	6
Dislocated	6	6
Infiltrated	8	5
Infiltrated + dislocated	3	1
Damaged	0	5

Note. *"Infiltrated" fasciculus – prior to surgery the fasciculus can't be reconstructed, it is located in the area of the tumor, but there are minor or no speech abnormalities; "dislocated" fasciculus – the fasciculus is located at the periphery of the tumor, it is deformed due to tumor growth; "injured" fasciculus – it can't be reconstructed after surgery, it is located in the area of the tumor, speech abnormalities are arised.*

As it can be seen from Table 2, according to preoperative MR tractography the arcuate fasciculus was not infiltrated in 12 cases and infiltrated in 11 cases. At the same time, according to the data of postoperative MR tractography, fasciculus damage were observed in 5 patients, among them 3 cases of direct rupture (with a microsurgical instrument) and 2 cases of indirect damage (ischemia).

When analyzing the tumor size based on preoperative MRI data, it was revealed that in 5 cases the tumors were up to 3 cm in diameter, in 15 cases – from 3.0 to 6.0 cm, in 3 cases – more than 6 cm.

Intraoperative examinations

Frontal lobe tumors. During intraoperative electrical stimulation of the cortex, Broca's area was detected in 8 of 11 patients with frontal lobe tumors. Its detection during electrical stimulation was accompanied by speech arrest or perseverations of previous words when naming pictures, which was typical for efferent motor aphasia according to A.R. Luria (Broca's aphasia). Coincidence

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of Broca's area detected during fMRI and direct stimulation of the cortex (DSC) was established in 7 of 8 patients.

During subcortical stimulation, speech disorders were similar to those in Broca's aphasia (e.g., perseveration, speech arrest). In 6 patients, with electrical stimulation of the subcortical areas (at a depth of about 2.5 cm), acoustic-mnestic aphasia (nominative) was determined in the form of forgetting the words, i. e., with stimulation of the deep posterior areas of the frontal lobe, speech effects were found that were very similar to those with stimulation of the Wernicke area of the temporal lobe (the so-called conduction aphasia).

Temporal lobe tumors. During electrical stimulation of the cortex, temporal speech areas were detected in 5 of 8 patients with temporal lobe tumors. A typical picture of speech disorders of the acoustic-amnestic aphasia type was observed [3]. When naming pictures (usually objects) during electrical stimulation, patients have forgotten the words, have tried to describe the function of objects in the pictures as well as the literal paraphasias have appeared. Sometimes such minor disorders as difficulties in understanding instructions were noted (patients reasked them). Coincidence of Wernicke's area, detected during fMRI and PSC, was observed in 3 of 5 patients.

During subcortical stimulation, naming disorders were also observed in the form of forgetting the words and literal paraphasias. At the same time, in 4 patients, the motor speech disorders were detected during electrical stimulation of the subcortical areas (at a depth of about 3.0 cm). Patients experienced difficulties with the beginning of word pronouncing up to speech arrest (as with stimulation of Broca's area). In mild cases the "stumbling" was observed when naming and perseveration of words and syllables, some patients began to "stretch" the words and pronounce them by syllables.

Thus, the stimulation of the deep posterior parts of the temporal lobe revealed speech effects very similar to those observed during stimulation of the Broca's area of the frontal lobe (the so-called conduction aphasia). The electrode location corresponded to the projection of the arcuate fasciculus, which was confirmed by postoperative MR tractography data in some patients.

Parietal lobe tumors. No speech disorders were determined during electrical stimulation of the parietal lobe cortex. During subcortical electrical stimulation, the speech disorders were detected in all 4 patients with parietal lobe tumors. In 3 patients, the speech disorders typical for stimulation of Wernicke's area (forgetting words, literal paraphasias) were noted; in 1 patient, speech disorders typical for stimulation of Broca's area (impaired speech initiation) was observed. Thus, the conduction aphasia was detected.

Postoperative examinations

In early postoperative period, the following deterioration of speech functions was found in 17 patients: the appearance of new speech disorders – in 13 cases, an increase in existing speech disorders – in 4 cases. In 4 of these patients, speech disorders corresponded only to the site of surgery – temporal (nominative aphasia) in interventions on the temporal lobe, frontal aphasia (Broca's aphasia) – in surgeries on the frontal lobe.

However, in 13 patients, the speech disorders after surgery were complex, namely, there was a combination of damage signs of the frontal and temporal lobes, i.e. acoustic-amnestic aphasia was combined with a distinct motor component of speech disorder or vice versa. In 6 of these 13 patients, the tumor was located in the frontal lobe, in 3 cases – in the temporal lobe, and in 4 patient – in the parietal lobe.

Among 3 patients with a frontal lobe tumor with negative mapping of Broca's area in PSC and a "positive" Broca's area according to preoperative fMRI data, the speech disorders developed in 1 patient and were conductive, rather than motor, aphasia.

Among 3 patients with a temporal lobe tumor with negative Wernicke's area mapping in PSC and a "positive" Wernicke's area according to preoperative fMRI, the speech disorders observed in 2 patients: one developed only conduction aphasia, and the other – only sensory.

Speech disorders were more pronounced and occurred more frequently in those patients who had arcuate fasciculus infiltration according to preoperative MR tractography. MRI volumetry performed in all patients during the first 48–72 hours after surgery showed that subtotal resection was performed in 17 cases, and partial resection was achieved in 6 cases.

Evaluation of speech functions in 3–6 months after surgery

The follow-up was performed only for those patients who had postoperative speech function deterioration. Among them only 13 patients were examined. The complete or significant recovery of speech function was observed in 10 patients. The permanent speech disorders were revealed in 3 patients. In these 3 patients, direct anatomical damage of the arcuate fasciculus was detected by postoperative MR tractography. At the same time, in 2 patients with ischemic damage of the arcuate fasciculus according to the results of postoperative MR tractography, the complete recovery of speech was observed in 6 months after.

Clinical case 1. *The female patient C., 32 years old, with anaplastic oligodendroglioma (Grade 3) in the left parietal lobe. From the patient's medical history an epileptic seizure occurred about 2 months ago.*

Neuropsychological examination before surgery revealed that speech and writing are intact. MRI data are presented in Fig. 1.

Intraoperative monitoring (awake craniotomy) was the followng: at the end of tumor resection, against the background of continuous subcortical electrical stimulation (current intensity 4 mA) during free dialogue in the parietal *lobe at a depth of about 3 cm, speech disorders (forgetting and omission of words, literal paraphasias) arose (see Fig. 1, e: zones 2, 17, 75).*

The neuropsychological examination just after surgery revealed that the patient has acoustic-amnestic aphasia (forgets names of objects in pictures – temporal type) combined with frontal motor aphasia (abundance of perseverations, including when writing – total agraphia due to perseverations). The conduction aphasia with damage of the arcuate fasciculus, connecting the functions of the temporal and frontal lobes, was stated (see Fig. 1, g).

There were no speech disorders in 3 months after surgery.

Clinical case 2. *The female patient R., 32 years old, with oligodendroglioma (Grade 3) in the left temporal lobe and supramarginal gyrus of the parietal lobe. From the patient's medical history: patient began to notice that recently, at the slightest distraction, she immediately forgot what she had read.*

The neuropsychological examination before surgery revealed that the speech and writing were preserved with a clear decrease in auditory-verbal memory in the delayed link. The preoperative MRI data are presented in Fig. 2.

The data of intraoperative monitoring (awake craniotomy) were the following: during electrical stimulation of the cortex

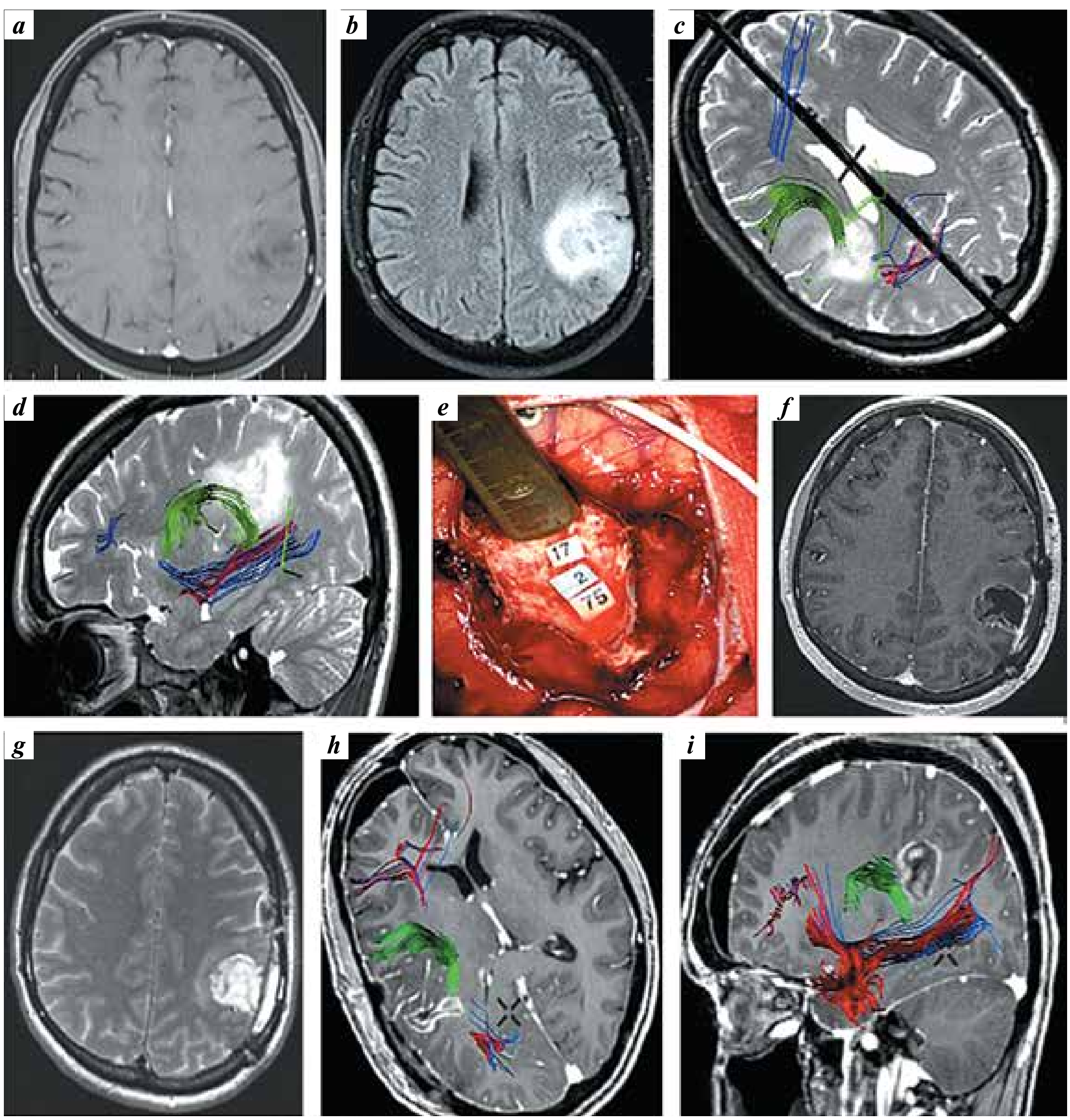

Fig. 1. *Data of female patient S.: a, b – magnetic resonance imaging (MRI) before surgery: axial scans in contrast-enhanced T1-weighted (a) and T2 FLAIR modes (b); c, d – magnetic resonance tractography before surgery: arcuate fasciculus (infiltrated) is shown in green: it is incorporated into the tumor along the posterior boundary; inferior fronto-occipital (shown in blue) and inferior longitudinal (shown in red) fasciculi are intact; e – intraoperative image: figures 2, 17, 75 denote the arcuate fasciculus; f, g – MRI after surgery: axial scans in contrast-enhanced T1-weighted (f) and T2-weighted modes (g); h, i – magnetic resonance tractography after surgery: arcuate fasciculus is shown in green, it is located near the postoperative cavity, inferior fronto-occipital and inferior longitudinal fasciculi are intact*

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(current intensity 4 mA) literal paraphasias were detected in the posterior parts of the superior temporal gyrus anterior to the tumor; at the end of tumor resection, against the background of continuous subcortical electrical stimulation (current intensity 4 mA) during free dialogue in the posterior-superior parts of the temporal lobe at a depth of about 3 cm, a distinct motor component of speech disorders was detected – the perseveration of words and syllables, up to the complete inability to begin pronouncing a word (speech arrest, as with stimulation of Broca's area) (see Fig. 2, f: zones G, P). At this stage, tumor resection was stopped.

The postoperative neuropsychological examination was the following: the patient showed features of temporal acoustic-amnestic aphasia (she forgot the name, but described the object) in combination with frontal motor aphasia (abundance of perseverations, including when writing – agraphia, because of perseverations she could not even write her last name). The conduction aphasia because of arcuate fasciculus damage was stated (see Fig. 2, h, i).

DISCUSSION

The current understanding of the neuroanatomical basis of language functions is based on the study of models that include many areas of the cerebral cortex (superior and inferior frontal gyri, inferior parietal lobule, superior and middle temporal gyri) and white matter tracts (frontal oblique fasciculus, arcuate fasciculus, inferior fronto-occipital fasciculus, and other fibers) [10, 11].

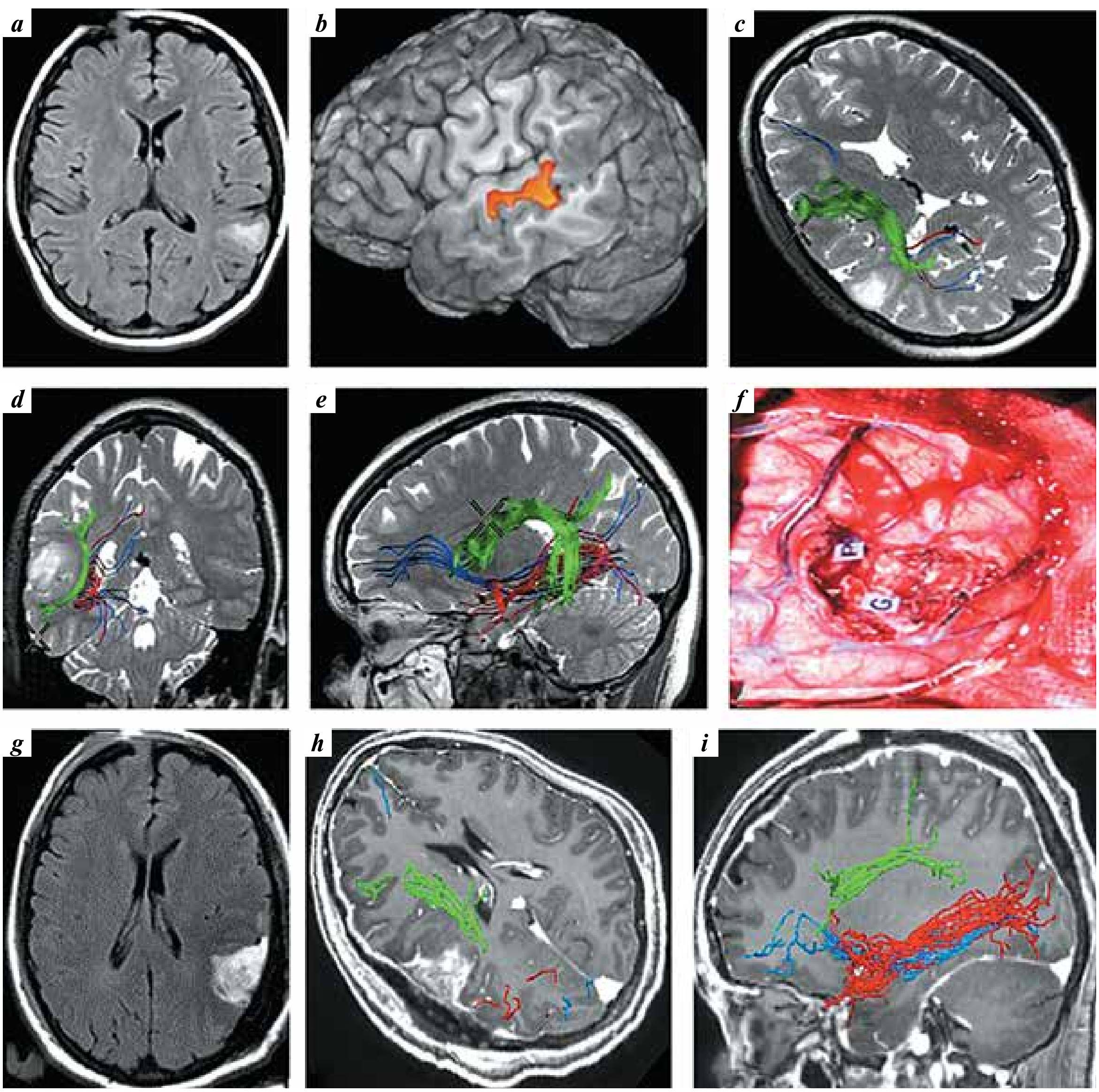

Fig. 2. *Data of female patient R.: a – magnetic resonance imaging (MRI) before surgery: axial scan in FLAIR mode; b – preoperative functional MRI: Wernicke's area is shown in orange (located at the front of the tumor); c–e – magnetic resonance tractography before surgery: arcuate fasciculus (intact) is shown in green: it is located very close to the posterior border of the tumor; inferior fronto-occipital (shown in blue) and inferior longitudinal (shown in red) fasciculi are intact; f – intraoperative image: letters G and P denote the arcuate fasciculus; g – MRI after surgery: axial scan in T2 FLAIR mode; h, i – magnetic resonance tractography after surgery: arcuate fasciculus is shown in green; inferior fronto-occipital and inferior longitudinal fasciculi are intact*

The numerous cases of transient postoperative aphasia during surgical resection (with awakening) of gliomas located in the speech-dominant hemisphere [2, 12, 13] are described in literature. To reduce the likelihood of postoperative speech deficit, the intraoperative mapping of not only cortical speech areas, but also the long association tracts is used. The parameters and current intensity during stimulation of association tracts are of great importance.

According to H. Duffau et al., almost 80 % of patients immediately after awakening surgeries on the dominant hemisphere develop speech disorders. In 3 months after operation, up to 95 % of patients do not have neurological deficits [14]. H. Duffau et al. used a current of 2 mA.

According to the results of other authors, who stopped resection at a current intensity of 6 mA, the transient speech disorders occurred in 60 % of patients, and the permanent speech disorders remained in almost 10 % of patients [13]. In our study, an increase in speech disorders in the early postoperative period was observed in 75 % of patients, and permanent speech disorders were in 15 %, while we used a current intensity of 4 mA.

The lower the current intensity at which the resection is stopped, the more radical the tumor removal, but also the greater the probability of tract damage [15]. As it is known, the current intensity has a direct interdependence with the distance over which it extends, with an approximate ratio of 1 mm – 1 mA (the "golden rule" of neurophysiology). This rule applies only to a monopolar electrode, as proven in Bello's work on the pyramidal tract [3].

That is why, in our study we used monopolar stimulation to map the arcuate fasciculus. The monopolar electrode was attached to a vacuum aspirator, which allowed continuous subcortical electrical stimulation during tumor resection. A bipolar electrode was additionally used for point localization of speech functions. In our series of observations, the arcuate fasciculus was detected in 16 (70 %) of 23 patients.

This is due to the fact that we used a current of 4 mA for subcortical stimulation. In patients in whom the arcuate fasciculus was not detected, the distance from the tumor to the one was about 1.0–1.5 cm. In D. Mato et al. study, the arcuate fasciculus was detected in only 33 % of patients. This is due to the fact that in half of these patients, the arcuate fasciculus was located at a large distance from the tumor [12].

The arcuate fasciculus has a significant extent in the cerebral hemispheres. The fibers of this tract connect the inferior frontal gyrus with the superior and middle temporal gyri and pass through the deep parts of the frontal, parietal and temporal lobes [16].

An increase in speech disorders in the early postoperative period can be caused by both anatomical damage of the arcuate fasciculus and its functional insufficiency [15]. The anatomical damage of this tract during surgery can subsequently lead to permanent speech disorders.

According to the latest data [3], the cause of functional insufficiency of the white matter tracts is spasm of small arteries supplying the tract fibers, which is not taken into account in postoperative MR tractography (while the tract is preserved). The bulk preservation of the arcuate fibers ensures the speech recovery in the late postoperative period.

In our study, the number of patients with increasing speech disorders in the early postoperative period was greater (75 %) than the number of patients with anatomical damage of the arcuate fasciculus according to postoperative MR tractography (22 %). This can be explained by the functional insufficiency of the arcuate fibers.

The postoperative MR tractography revealed the direct intraoperative damage of arcuate fasciculus in 3 cases (13 %). This is due to the fact that dynamic monopolar stimulation was not used during resection (only bipolar stimulation was performed), and the surgeon critically approached the speech tracts. In 2 patients, the speech disorders occurred at the end of tumor resection during hemostasis using bipolar coagulation.

The postoperative MR tractography revealed an ischemic area of the tract. H. Duffau et al. recommend not to use bipolar coagulation near the fibers, but to use only hemostatic gauze, however, they perform awake surgery mainly for low-grade gliomas.

The abovementioned speech disorders regressed in the majority of patients (85 %) in 3–6 months after surgery. The permanent speech disorders were observed only in those patients (15 %), who according to postoperative MR tractography had a direct anatomical disruption of the integrity of the arcuate fasciculus.

A significantly smaller number of publications analyze the complex speech syndrome in the postoperative period after awake craniotomy [17, 18]. The speech syndrome during damage of arcuate fasciculus, combining features of temporal and frontal damage, was previously described by us in a smaller group of patients and interpreted as conduction aphasia in case of arcuate fasciculus damages [5, 7, 19].

The present study a continuation of the accumulation and analysis of observations of patients with brain gliomas who underwent awake craniotomy. The peculiarity of our observation series is the localization of tumors in the frontal, temporal and parietal lobes of the speech-dominant left hemisphere, as well as the use of subcortical mono- and bipolar electrical stimulation with mapping of all parts of the arcuate fascivulus as well as thorough analysis of pre-, intra- and postoperative speech disorders.

As a result of this study, it was established that the nature of speech disorders depended on the localization of the tumor within the left hemisphere. When the tumor was localized in the posterior frontal region, especially when spreading to the subcortical areas, there was a possibility of arcuate fasciculus damage during surgery.

That is why, in some patients, the speech disorders were limited exclusively to frontal symptoms (perseverations), while in others, the speech symptoms were added "at a distance" – temporal symptoms (forgetting words), caused by damage of the anterior part of the arcuate fasciculus, which passes through the frontal lobe, i. e., so-called conduction aphasia was detected.

When the tumor was located in the posterior temporal region, in addition to the speech disorders of the temporal type, the frontal symptoms could arise. When the tumor was localized in the parietal region, the speech symptoms arose only "at a distance" (the temporal or frontal type).

CONCLUSION

During awake brain surgeries, when the tumor is located in the left cerebral hemisphere, it is important to map the arcuate fasciculus in the deep parts of the frontal, temporal or parietal lobes. With subcortical electrical stimulation, the arcuate fasciculus was identified in 70 % of cases; according to postoperative MR tractography, the integrity of the arcuate fasciculus was disrupted in 22 % of cases (direct injury or ischemia).

The deterioration of speech functions in the early postoperative period was detected in 75 % of patients. In the early postoperative period, the main cause of speech functions deterioration associated with the arcuate fasciculus is its functional insufficiency but not anatomical damage. These speech disorders regress in the majority of patients (85 %) in 3–6 months after operations.

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